Time-variable gravity field recovery from reprocessed GOCE precise science orbits

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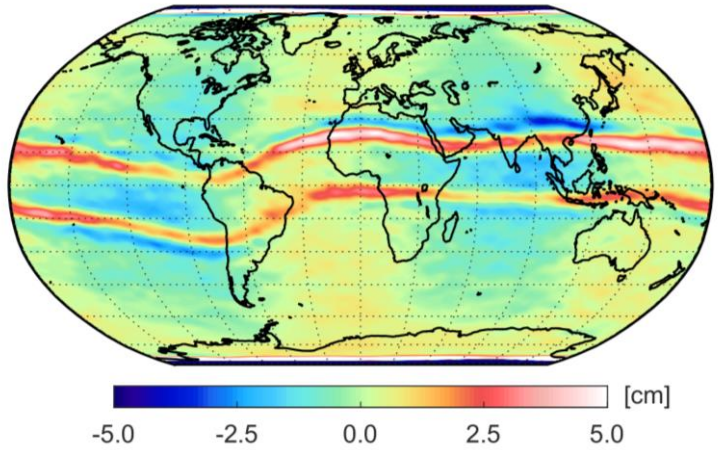
Introduction

- ESA's satellite mission GOCE (2009 – 2013)
  - Gravity Field and Steady-State Ocean Circulation Explorer
  - Sun-synchronous orbit, mean altitude ~255 km
  - Core instrument: Gravity gradiometer (consisting of six accelerometers)

- Satellite-to-Satellite Tracking (SST)
  - Two dual-frequency GPS receivers
  - Primary instrument for
    - GPS-based orbit determination
    - GPS-based gravity field recovery

➢ ESA's GOCE Reprocessing campaign

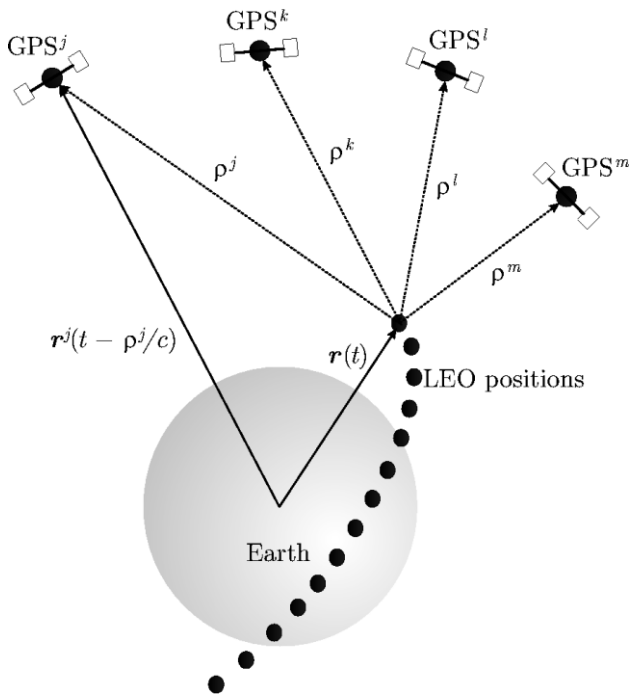
- Issues with operational GOCE orbits (Jäggi et al., 2015)



  - Orbit positions affected by large ionospheric changes
  - Limitations for (time-variable) gravity field recovery

GOCE Reprocessing Campaign at AIUB

- Reprocessing of GOCE Precise Science Orbits (PSO)
  - Bernese GNSS software using reprocessed GPS products (Sušnik et al., 2020)
  - GPS data weighting strategy to mitigate ionospheric effects (Schreiter et al., 2019)
    - ➢ Unweighted and weighted reprocessed PSO
- Gravity field recovery (Celestial Mechanics Approach)
  - 1-sec reprocessed kinematic GOCE positions + covariance information
  - Use of GOCE accelerometer (ACC) data as part of the force model
- Computed gravity field solutions:



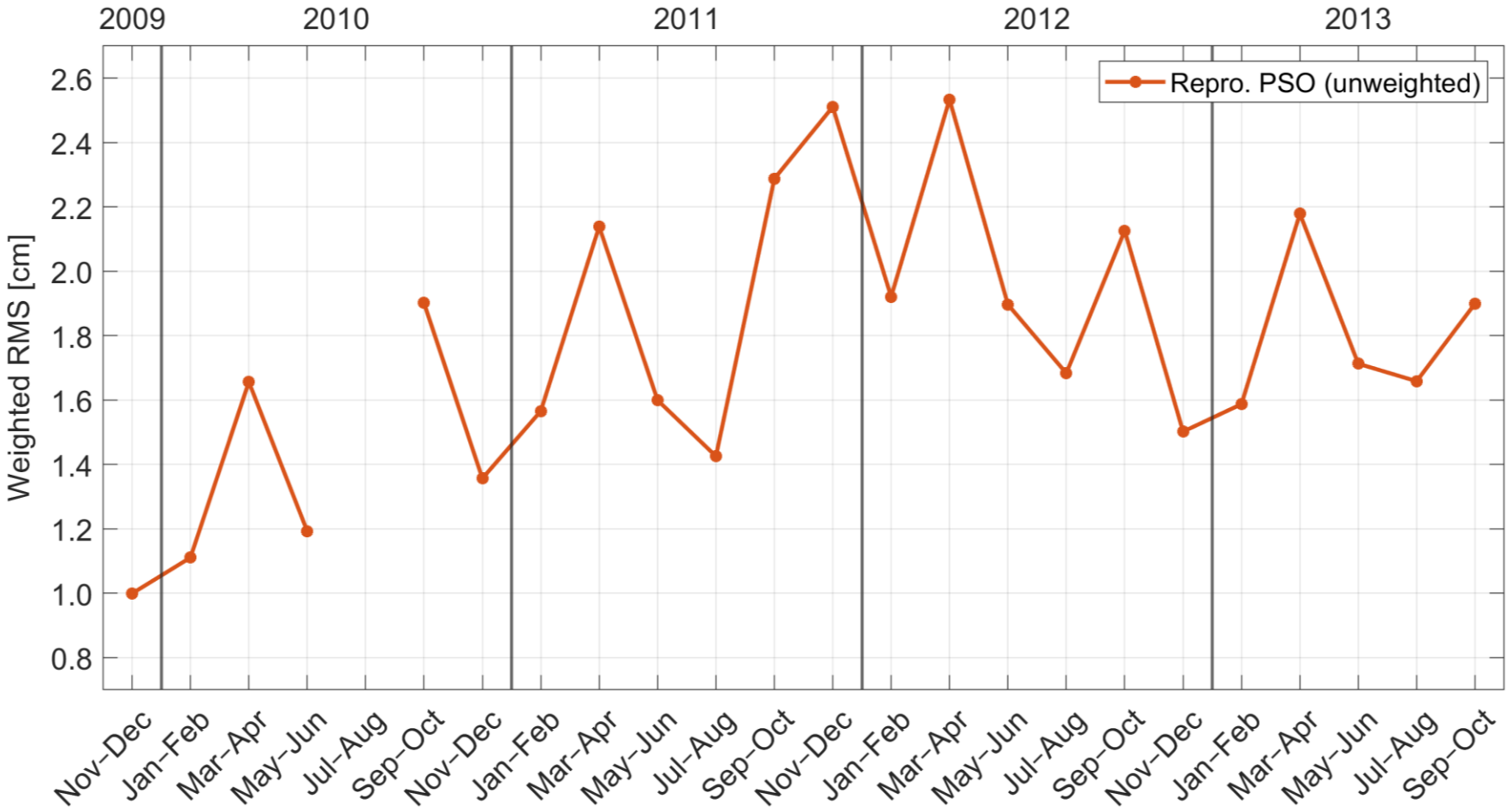
Reprocessed PSO (unweighted)

Reprocessed PSO (weighted)

Reprocessed PSO (weighted) + ACC data

GPS-based gravity field recovery with GOCE

- Quality of bi-monthly gravity field solutions



Geoid height differences w.r.t. ITSG-Grace2018 (300 km Gauss-filtered)

GPS-based gravity field recovery with GOCE

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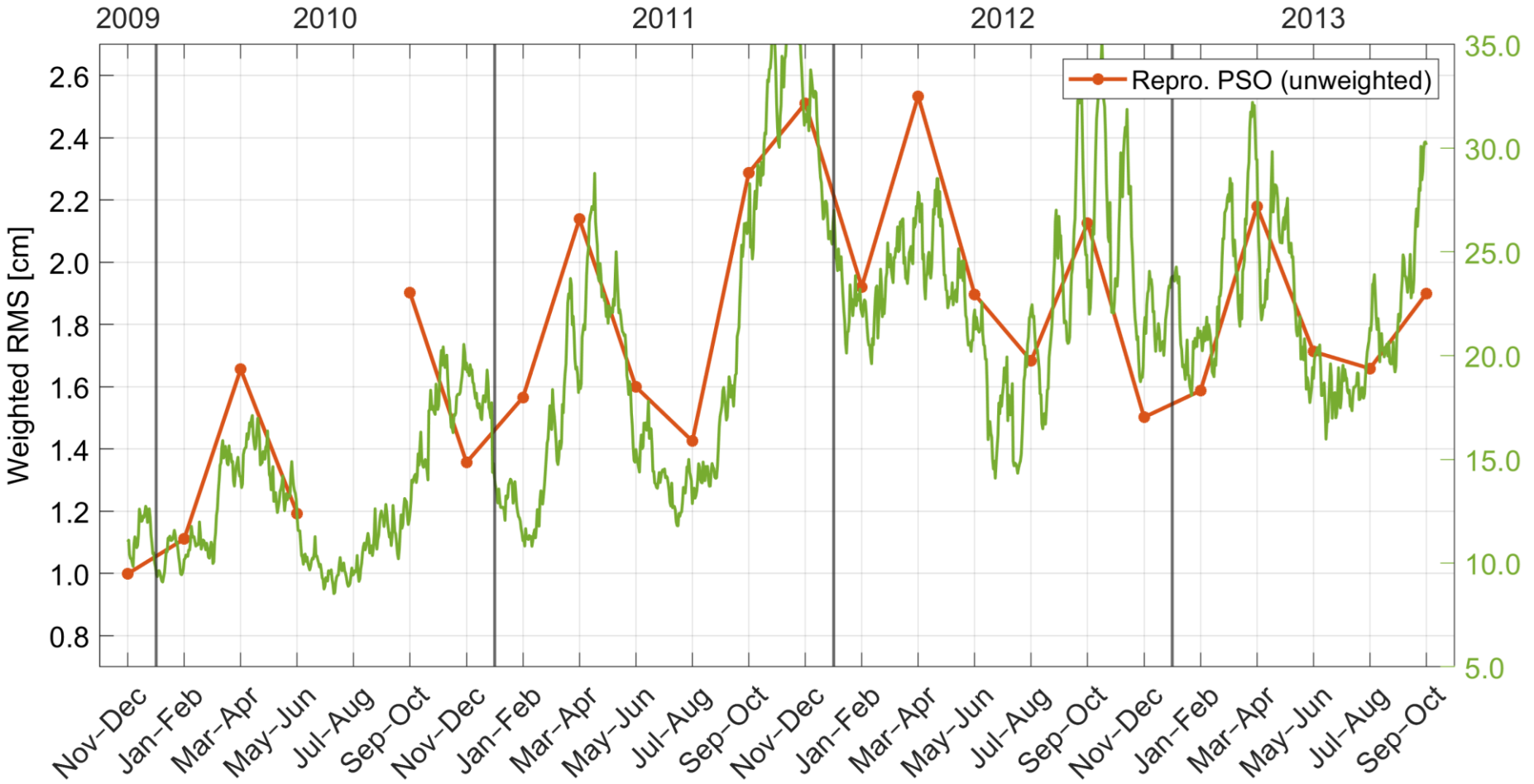
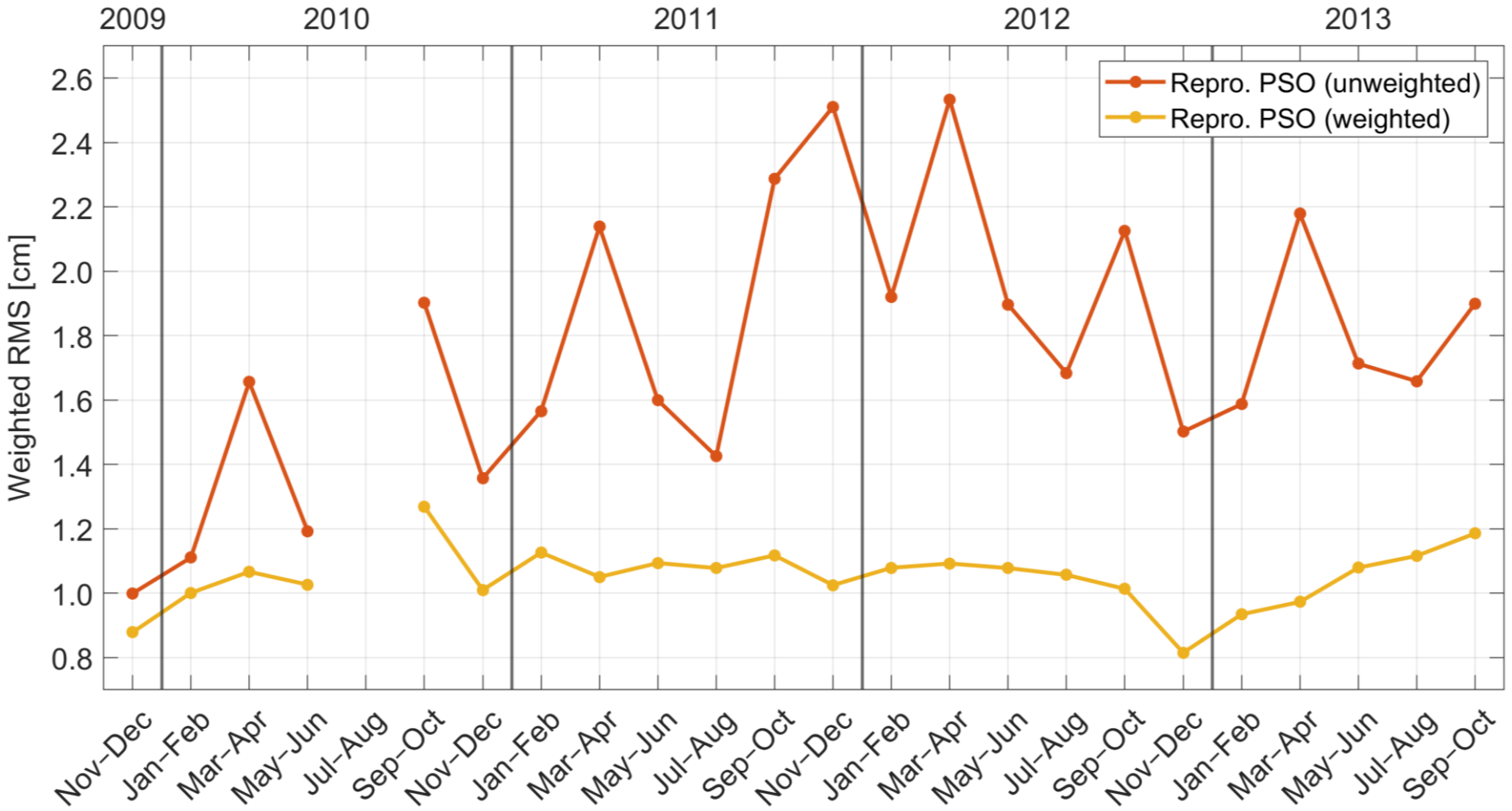


Mean total electron content [TECU]

GPS-based gravity field recovery with GOCE

- Quality of bi-monthly gravity field solutions



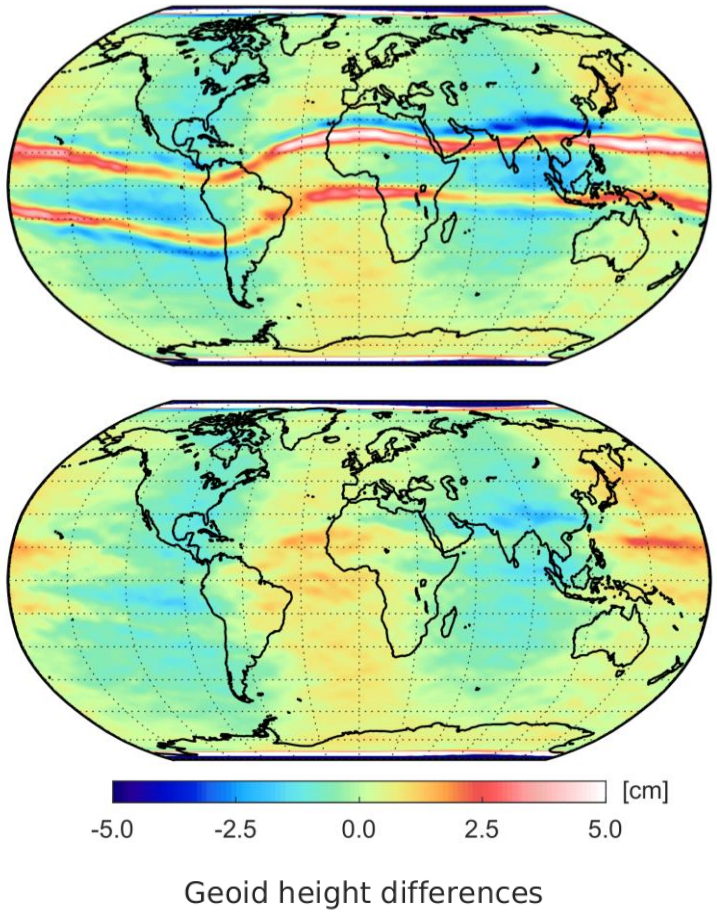
Geoid height differences w.r.t. ITSG-Grace2018 (300 km Gauss-filtered)

Improvements in long-term solutions

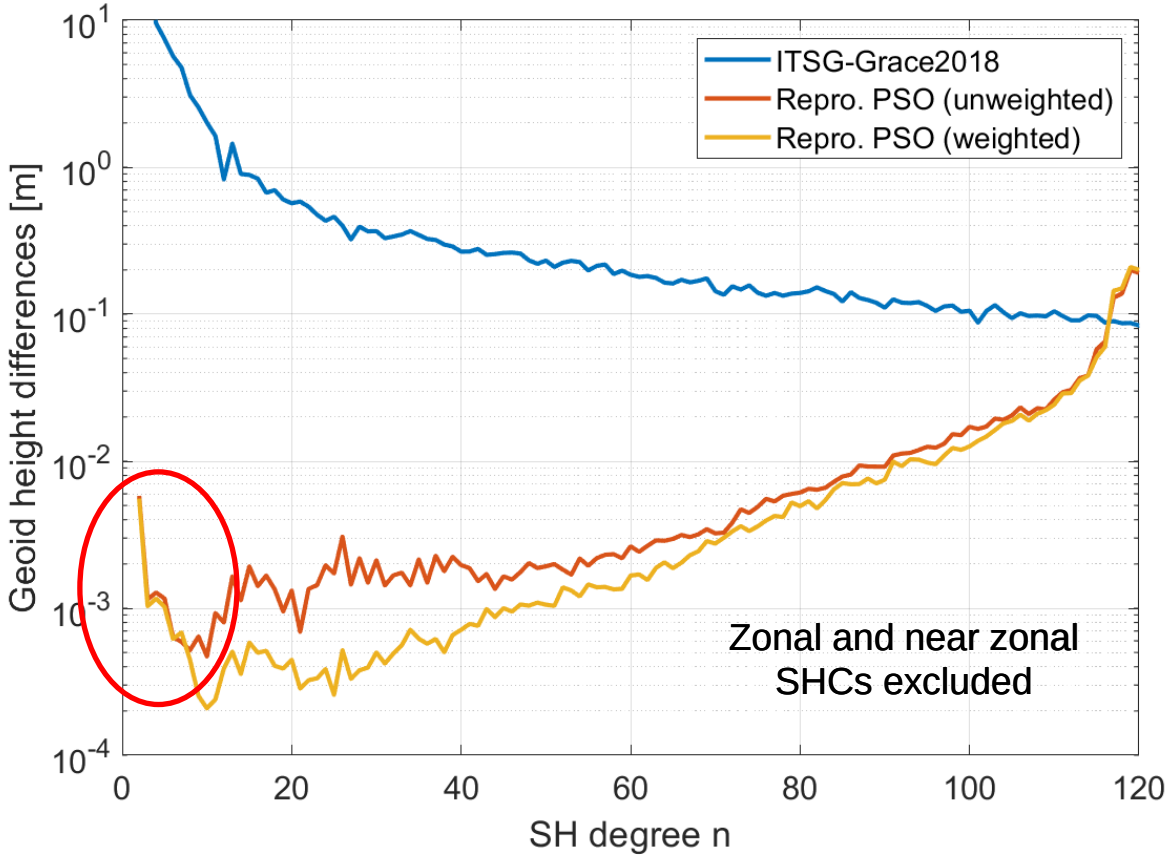
- Geoid height differences

unweighted PSO

weighted PSO



- Difference degree amplitudes

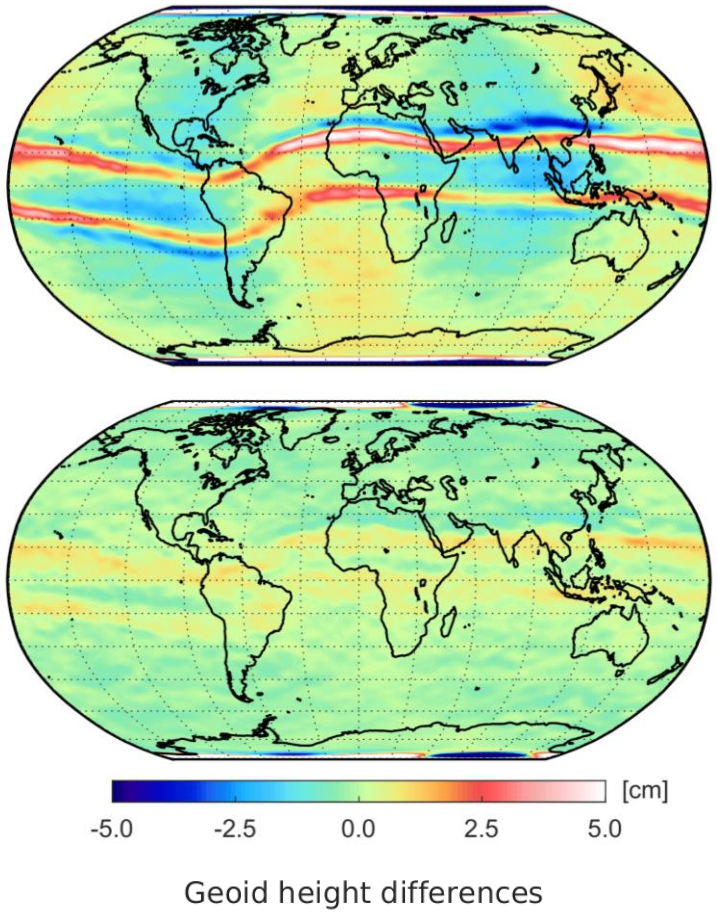


Improvements in long-term solutions

- Geoid height differences

unweighted PSO

weighted PSO + ACC



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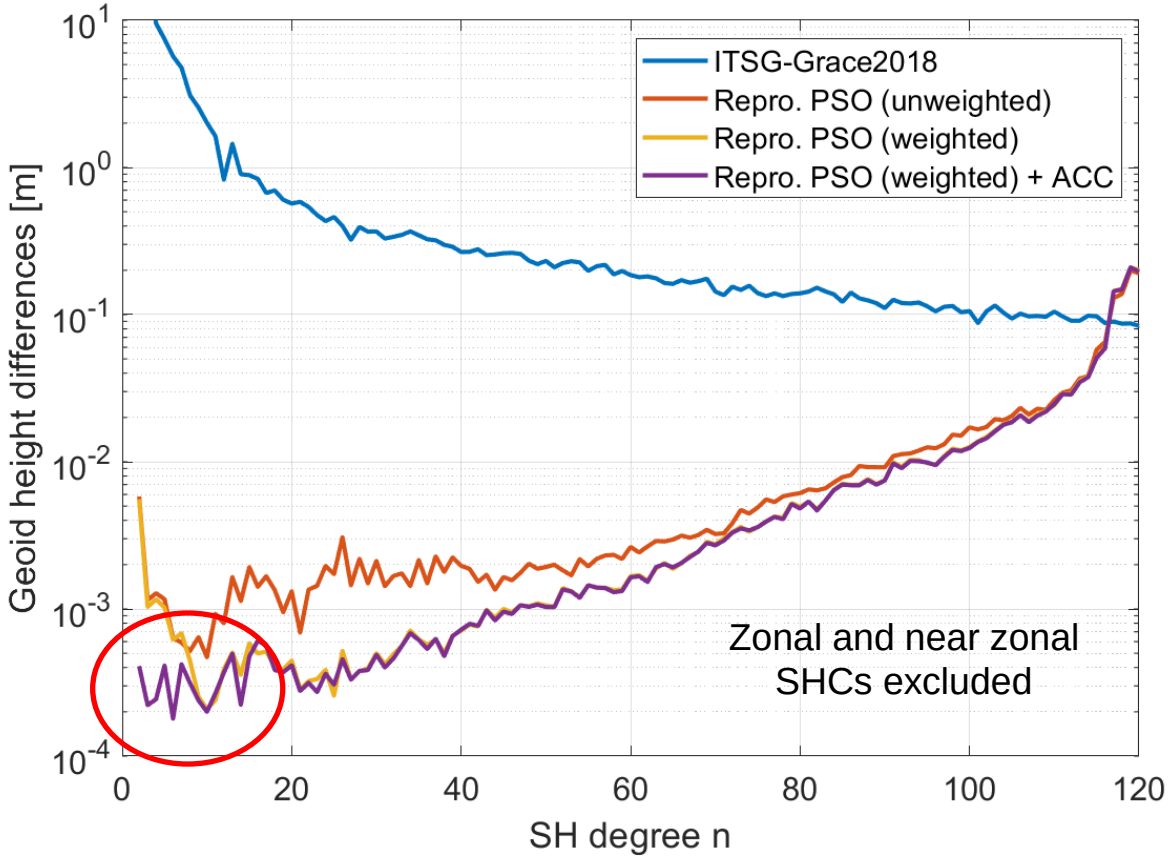

Time-variable gravity field recovery

- Set up of (static) SH coefficients up to d/o 120
- Parameter transformation on the level of normal equations (for coefficients up to d/o 10)

$$x_k = a_k \cdot [\omega\,(t_i - t_0)] + b_k \cdot \cos[\omega\,(t_i - t_0)] + c_k \cdot \sin[\omega\,(t_i - t_0)] + d_k$$

Trend term | Cosine term | ← Annual variations → | Sine term | Offset

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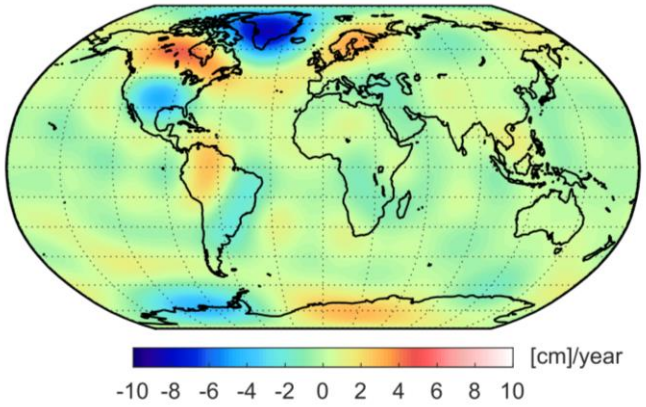
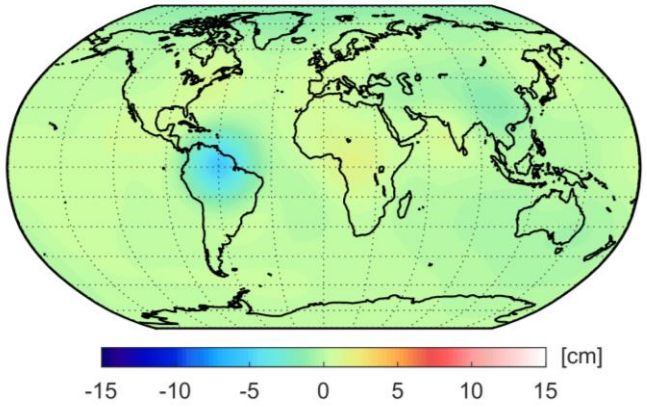
- Reference values from GRACE K-band data (a posteriori fit of monthly ITSG-Grace2018 solutions)

Trend



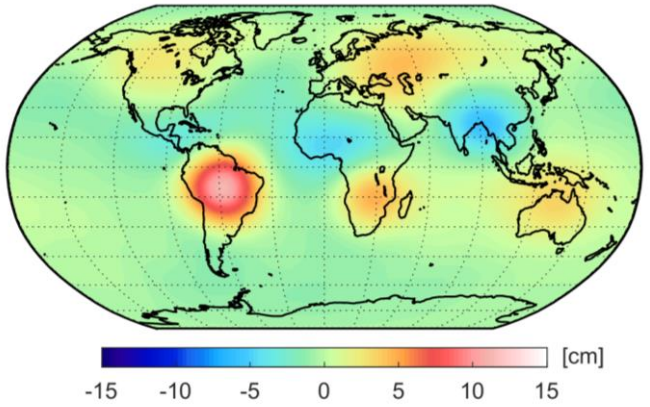
300 km Gauss-filtered

Cosine



1500 km Gauss-filtered

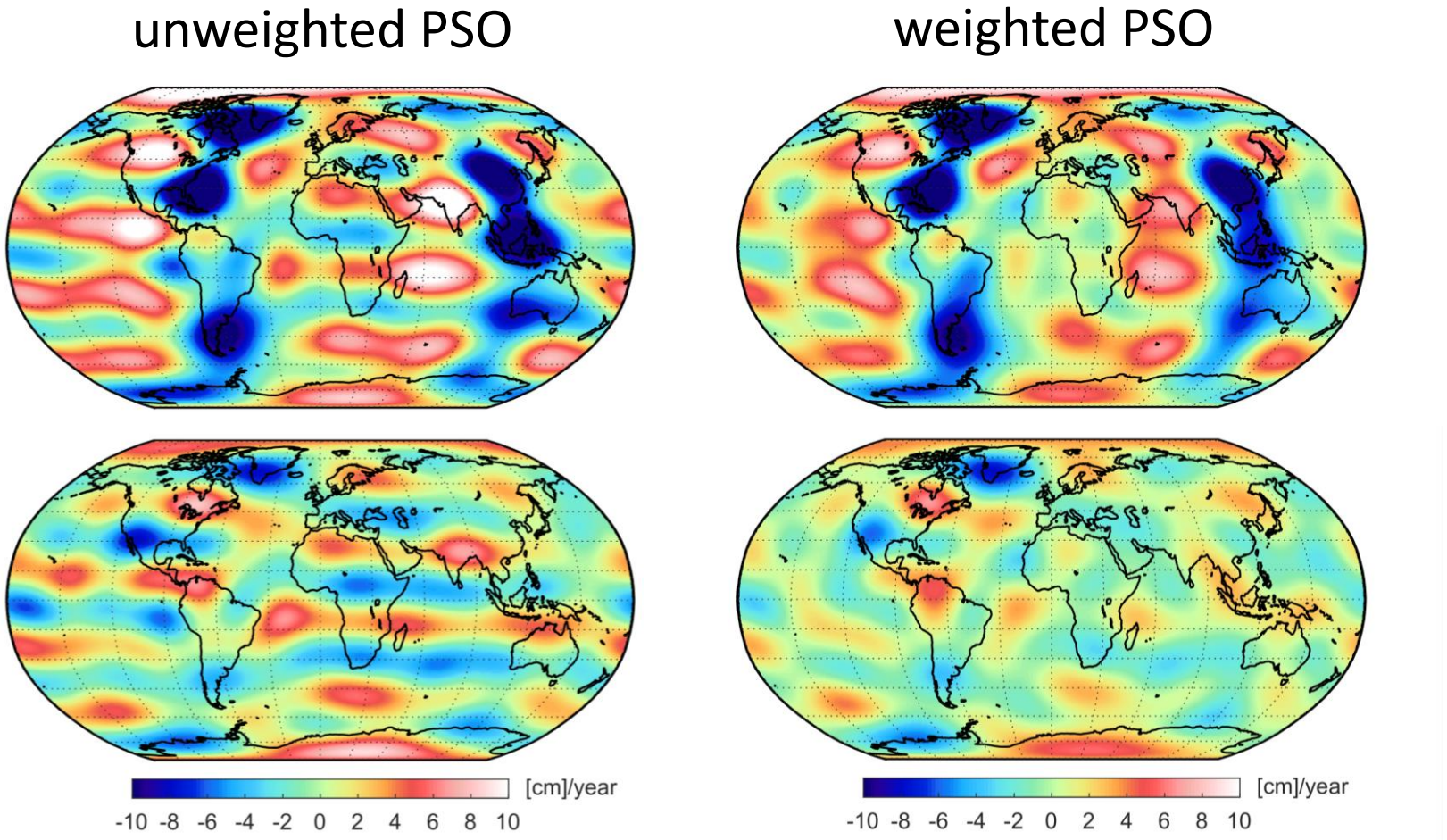
Sine



1500 km Gauss-filtered

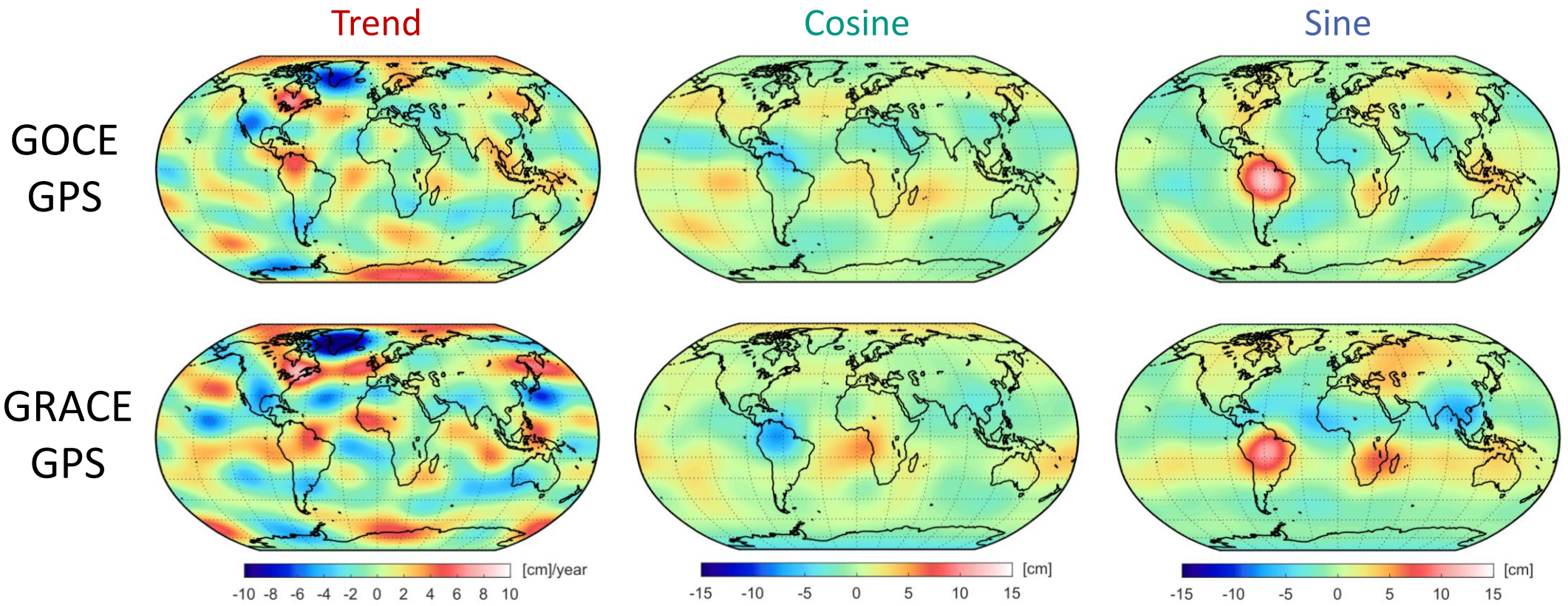
Equivalent water heights

Estimated trends from GOCE (Nov 2009 − Oct 2013)



Equivalent water heights

Time-variable gravity field signals (Nov 2009 − Oct 2013)



Equivalent water heights

Summary

- Complete reprocessing of the GOCE Precise Science Orbits (PSO)
- Improved GPS-based gravity field recovery based on reprocessed PSO

- Time-variable gravity field recovery from reprocessed PSO
  - Major time-variable signals can be recovered from about 4 years of GOCE-GPS data
  - Use of GOCE accelerometer data is crucial to derive meaningful linear trends
  - Temporal variations obtained from GOCE are comparable to those from GRACE-GPS data

RMS values w.r.t. ITSG-Grace2018

Solution	Trend [cm/year]	Cosine [cm]	Sine [cm]
GOCE-GPS	1.27	1.44	1.37
GRACE-GPS	1.87	1.35	1.01

References

Jäggi A, Bock H, Meyer U, Beutler G, van den IJssel J (2015): GOCE: assessment of GPS-only gravity field determination. Journal of Geodesy 89(1):33–48, DOI:10.1007/s00190-014-0759-z

Schreiter L, Arnold D, Sterken V, Jäggi A (2019): Mitigation of ionospheric signatures in Swarm GPS gravity field estimation using weighting strategies. Annales Geophysicae 37(1):111–127, DOI:10.5194/angeo-37-111-2019

Sušnik A, Grahsl A, Arnold D, Villiger A, Dach R, Beutler G, Jäggi A (2020): GOCE: Validation of the EGSIEM-REPRO GNSS orbits and satellite clock corrections. Remote Sensing 12(14):2322, DOI:10.3390/rs12142322

Publication in preparation:

Arnold D, Grombein T, Schreiter L, Sterken V, Jäggi A: Reprocessed precise science orbits and gravity field recovery for the entire GOCE mission.

Thank you for your attention